OPERATING AND INSTRUCTION MANUAL

MODEL VM-235 S-740

TRANSISTORIZED PHASE ANGLE VOLTMETER

NORTH ATLANTIC

industries, inc.

OPERATING AND INSTRUCTION MANUAL

MODEL VM-235 S-740

TRANSISTORIZED
PHASE ANGLE VOLTMETER

Revision A - October 9, 1964
Revision B - November 23, 1965

NORTH ATLANTIC INDUSTRIES, INC.
Plainview New York

Copyright 1961, 1964 by North Atlantic Industries, Inc.
Printed in U.S.A.

TABLE OF CONTENTS

		PAGE
I.	Specification	1.1
II.	General Description	2.1
III.	Operating Instructions	3.1
	Controls	3.1
	"RANGE" Switch	3.1
	"FUNCTION" Selector	3.1
	"DEGREES" Phase Dial	3.1
	Displays	3.1
	Meter	3.1
	"OVERLOAD" Lamp	3.2
	Fuse	3.2
	Operation	3.2
	Voltmeter (Not Phase Sensitive) Measurements	3.2
	To Measure the In-Phase & Quadrature Component of a Signal	3.3
	Phase Angle Measurements Using the Calibrates "DEGREES" Phase Dial	3.3
	Phase Angle Measurements Using E cos θ Characteristic	3.4
IV.	Theory of Operation	4.1
	General	4.1
	Amplifiers	4.1
	Phase Sensitive Rectifier	4.1
	Power Supplies	4.2
V.	Maintenance	5.1
	Cover Removal	5.1
	Crystal Diode & Transistor Replacement	5.1
	Amplifier Replacement	5.1
	Figure 5.1 Block Diagram	5.2
	Figure 5.2 Schematic	5.3
	Figure 5.3 Filter Characteristic, Typical	5.4
	Replacement Parts List	5.5

TABLE OF CONTENTS (Cont'd)

	PAGE
VI. Calibration Test Procedure----------	6.1
Voltage Calibration----------	6.1
Figures 6.2.1, 6.2.2----------	6.2
"DEGREES" Phase Dial Alignment----------	6.3
Phase Bridge Alignment----------	6.4
Input Attenuator Adjustment----------	6.5
Location of Adjustments----------	6.7
VII. Warranty----------	7.1

INSTRUCTION MANUAL SUPPLEMENT

VM-235 - S740

Please note that in this unit the standard pilot and overload light configurations have been changed. The overload light is now red, and the pilot light is now white.

This change requires a change in Part Numbers as follows:

P/N 802718, Lens, Clear, replaces Red Lens P/N 800397

P/N 802719, Lens, Red, replaces Clear Lens P/N 800396

Supplement No. 207

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

INSTRUCTION MANUAL SUPPLEMENT

VM-235

The 500052 assembly contains the following parts preceding Serial No. 5787.

Designation	Description	NAI Part No.
R37	Resistor, Comp., 68K, 1/2W, 5%	800635
R38	Resistor, Comp., 20K, 1/2W, 5%	800521
R39	Resistor, Comp., 1.2K, 1/2W, 5%	800522
Q2	Germanium Transistor Type #2N526	800652
C19	Capacitor, Tantalum, 33ufd, 10V	801190

Supplement No. 208

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

INSTRUCTION MANUAL SUPPLEMENT

HARMONIC REJECTION FILTER REPLACEMENT

The filters listed in this supplement are improved versions of the filters used previously. They are exactly interchangeable with those used in existing instruments.

The selection of the proper filter for any given instrument may be made simply by choosing the filter which covers the operating frequency of the instrument. This choice may be made by referring to the tabulation included with this supplement. The original filters were specified on the individual schematics and should not be reordered.

For improved accuracy these filters have been matched in sets and will be supplied as matched pairs when ordered as replacements.

PART NO.	USEABLE BAND	TYPICAL APPLICATION
201734-1	55Hz to 110Hz	60Hz
201734-2	110Hz to 220Hz	120Hz
201734-4	525Hz to 1050Hz	800Hz
201734-5	880Hz to 1760Hz	1KHz
201734-6	1760Hz to 3520Hz	2.4KHz
201734-7	3520Hz to 7040Hz	4.8KHz
201734-8	7040Hz to 14.1KHz	10KHz
201734-10	265Hz to 530Hz	400Hz
201734-11	27.5Hz to 55Hz	30Hz
201734-12	14.2KHz to 28.2KHz	20KHz

When these filters are used to replace older-type filters, it is necessary to change R7 from a 10K (NAI #801102) to a 15K (NAI #800066).

Supplement No. 211
2/2/67

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

SECTION I

SPECIFICATION

General:	The VM-235 covered by this specification is a Transistorized, Militarized Phase Angle Voltmeter. Filters are included in both signal and reference channels, as well as phase shift networks for use at a specific frequency of operation. A Reference Isolation Transformer is included in the reference channel. Optional features (See Addendum) include a Signal Isolation Transformer in the signal channel and provisions for the external connection of a meter in place of the one in the equipment.
VOLTAGE "RANGE":	Full-Scale Reading: 1 Millivolt to 300 volts in 12 separate ranges with meter scale calibrated in volts.
Frequency Range:	Instrument is calibrated for use at a specific frequency of operation (See Addendum) for "FUND", "0°" and "90°" "FUNCTION" Selector positions. In the "TOTAL" position, the instrument may be used from 20 cps to 15 KC (with optional Signal Isolation Transformer, 20 cps to 2.5 KC).
Accuracy:	as a voltmeter ("TOTAL"); ±2% from 30 cps to 5 KC and ±5% from 20 cps to 15 KC as a phase sensitive voltmeter; ±2% at frequency of operation and ±3% of full scale angle, using E cos θ characteristic 1° calibrated "DEGREES" phase dial
Signal Input Impedance:	Nominally, 1 megohm (with optional shielded Signal Isolation Transformer for balanced input; nominally, 100 Kilohms).
Reference Input:	External 115 volts reference required at the phase sensitive frequency of operation.
Calibration:	Zero center voltmeter reads RMS of Sine Wave. Voltage scales 3 - 0 - 3 and 10 - 0 - 10 volts, read E cos θ (in-phase vector of signal to reference as phase angle meter). "DEGREES"

Phase dial calibration 0° to 90° in 1° divisions. Two position Quadrant positions on "FUNCTION" Selector (ie "0°" and "90°").

"OVERLOAD": "OVERLOAD" alarm lamp set at 5 X full scale voltage.

Power: 115 ±10%, 50 - 440 cps. Approximately 4 watts at 400 cps.

Noise: Less than 2 microvolts, phase sensitive functions.

Harmonic Rejection: Greater than 55 db with filters and in-phase sensitive functions.

SECTION II

GENERAL DESCRIPTION

The VM-235 is a truly unique multifunctional instrument which will function as a sensitive voltmeter and (at a rated frequency) a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter, and a power factor meter.

CAUTION: TO AVOID THE PITFALLS OF GROUND LOOPS DUE TO MULTIPLE POINT GROUNDS, REFER TO THE SECTION IN THE APPLICATION NOTES TREATING THIS SUBJECT.

Signal and Power Inputs

All inputs to the VM-235 are brought through a connector on the rear of the unit. Each input is individually shielded and chassis ground is available through the connector. Careful attention must be given to the grounding of shields to avoid ground loops.

SECTION III

OPERATING INSTRUCTIONS

CONTROLS

"RANGE" Switch

This switch selects the full scale voltage indicated at each position.

CAUTION: MAXIMUM INPUT SIGNAL MUST NOT EXCEED 300 VOLTS AND MAXIMUM INPUT REFERENCE MUST NOT EXCEED 130 VOLTS, RMS.

"FUNCTION" Selector

The "FUNCTION" Selector is a front panel control used to select the desired mode of operation for the instrument. In the two phase sensitive positions, "0^{o}" and "90^{o}", the instrument is connected so as to read a voltage E cos θ, where θ is defined as the angle between the signal vector and the reference vector.

In the position marked "FUND" the instrument functions as a standard voltmeter and reads the total vector voltage of the fundamental signal. In the position marked "TOTAL" the signal filter is removed and the instrument functions as a standard voltmeter reading the entire input signal including harmonics.

"DEGREES" Phase Dial

This dial is calibrated to read the degrees of phase shift introduced by the calibrated phase shifter within the particular quadrant selected by the "FUNCTION" Selector. The actual calibration of this dial is non-linear. For this reason, should the dial ever be removed, the procedure under "DEGREES" Phase Dial Alignment of Section VI should be followed when reassembling.

DISPLAYS

Meter

The meter is a MIL type hermetically sealed, zero center, DC milliammeter calibrated to read the RMS value of a sine wave. For "TOTAL" or "FUND" readings, the needle deflects to the right. For phase sensitive "0^{o}" and "90^{o}" readings, the meter deflection may be either left or right.

CAUTION: BY ITS NATURE, THE INSTRUMENT IS REQUIRED TO HANDLE

INPUTS CONSIDERABLY IN EXCESS OF ITS FULL SCALE READING. DAMAGE CAN OCCUR IF THE SIGNALS ARE APPLIED IN A MANNER WHICH WILL DRIVE THE NEEDLE HARD AGAINST THE STOPS. THEREFORE, ALWAYS APPROACH A MEASUREMENT FROM THE LEAST SENSITIVE POSITION AND RETURN TO THIS POSITION BEFORE MAKING CIRCUIT ADJUSTMENTS.

"OVERLOAD" Lamp

The lamp marked "OVERLOAD" blinks whenever the signal exceeds a prescribed level. This indication warns of impending amplifier overload and the attendant inaccuracies which will occur when large, saturating signals are present. The "OVERLOAD" indicator is factory set at approximately five times full scale. Amplifier overload actually occurs around eight times full scale, and light remains on.

"FUSE"

The fuseholder mounted on the left, just behind the front panel contains a standard .25 amp cartridge fuse.

OPERATION

The instrument as received from the factory should indicate zero before being turned on. If it does not, reset the meter to read zero by means of the adjusting screw near the bottom of the meter face. This adjustment must be done with the power off and with the meter in a vertical or near vertical plane.

With the instrument plugged into the proper power source, turn on power. Allow the instrument to warm up about 3 minutes for stable operation. For precision phase measurements, additional time should be allowed for the reference and signal filters to reach equilibrium temperature conditions.

The series VM-235 instruments are all characterized by being designed for single frequency measurements. The use of selective filters in conjunction with an R-C phase shifter results in a phase shift and amplitude characteristic which is a function of the frequency of the input signal. The filter characteristic is shown in Figure 5.3.

Voltmeter (Not Phase-Sensitive) Measurements

1. Set the "RANGE" switch to the appropriate scale and the "FUNCTION" selector to the "TOTAL" or "FUND" position.

2. Read the meter from either the 0 - 3 scale or the 0 - 10 scale.

using the proper scale factor as determined by the "RANGE" selector position.

It will be noticed that with no input to the instrument, the meter needle deflects on the low ranges. This condition is normal and represents a true measurement of the stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to near zero.

To Measure the In-Phase and Quadrature Component of a Signal

1. Place "FUNCTION" selector in "0°" position. Set "DEGREES" Phase Dial at "0°" degrees.

2. The meter now reads the in-phase component of a signal. This is also E cos θ where θ is the angle between the reference and signal.

3. Switch the "FUNCTION" selector to "90°." The meter now reads the quadrature component or E sine θ. In general, one of these components is usually much smaller than the other and for greater accuracy, it is convenient to change the "RANGE" of the instrument. This can be done until the "OVERLOAD" lamp blinks thereby warning of an impending overload condition. This light indicates that the total signal exceeds five (5) times the full scale value. Measurements can be made for overloads up to eight times full scale at which time amplifier clipping takes place. Measurements under all these conditions will be most accurate if the zeroing process described in the appended Application Notes is followed.

Phase Angle Measurements Using the Calibrated "DEGREES" Phase Dial

1. Set the "FUNCTION" selector to a phase sensitive position, i.e. "0°" or "90°", so that the "DEGREES" phase dial may be adjusted for a null on the meter.

2. Set the "FUNCTION" selector to the phase sensitive position not used in Step 1. The "RANGE" switch should be set for a maximum on-scale deflection. To increase sensitivity, the "RANGE" switch may be set one position more sensitive. The meter should now read off-scale.

3. Repeat Step 1.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

4. Set the "FUNCTION" selector to the phase sensitive position used in Step 2 and determine the phase shift of the input signal using the following table:

"FUNCTION" Selector Position	Meter Deflection	Add "DEGREES" Phase Dial Reading to	Quadrant
0°	Right	0°	0°-90°
0°	Left	180°	180°-270°
90°	Right	90°	90°-180°
90°	Left	270°	270°-360°

Phase Angle Measurements Using E cos θ Characteristic

Accurate measurements of phase angle can be made using the E cos θ or E sine θ characteristic. Voltage measurements are made of the in-phase ("0°" position) or quadrature ("90°" position) component and of the fundamental signal ("FUND" position). The quotient will then be the cosine or sine of the unknown phase angle. Where the fundamental signal can be adjusted to full scale, the meter reading will be directly the sine or cosine of the phase angle. (This is the reference to a ±3% rating of full scale angle). Trigonometric tables, slide rule, or graphs included in the appended Application Notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure and for that reason it is suggested the Application Notes be reviewed before using this method.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

SECTION IV

THEORY OF OPERATION

General

The block diagram of Figure 5.1 will serve to illustrate the principle of operation of the Phase Angle Voltmeter.

The input signal to be measured is fed through an input capacitor to an isolation amplifier which drives the signal channel filter. For signals up to .3V full scale, the input goes directly to the amplifier. For the remaining scales, the input range multiplier attenuates these inputs by a factor of one thousand. Following the filter, the signal is again attenuated by the "RANGE" switch. The range multipliers are arranged so as to have a full scale voltage of 1 millivolt for all scales at the input to the meter preamplifier.

The meter amplifier consists of a preamplifier and an output amplifier which feeds the rectifier section of the voltmeter.

The reference channel consists of a Reference Isolation Transformer coupled to a second transformer which feeds the phase bridge. The output of the phase bridge is fed to the reference isolation amplifier which in turn is coupled to the reference filter. The output of the filter, in turn, feeds the reference amplifier. The reference amplifier drives the phase sensitive rectifier when the instrument is used in phase sensitive operation.

Amplifiers

The amplifier complement consists of the following fully transistorized and potted amplifiers:

1.	D-782013	Isolation Amplifier (2 used)
2.	D-782035	Meter Preamplifier
3.	D-782014	Meter Output Amplifier
4.	D-782015	Reference Amplifier

Phase Sensitive Rectifier

The phase sensitive rectifier circuit is a conventional ring demodulator. Its operation can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through resistor R10 and then the other end of the reverse cycle of the reference. The signal is therefore synchronously rectified through the meter movement. If the reference and signal are in phase, the average value will be a

maximum and the meter will read a maximum, with deflection to the right. If the signals are 90 deg. apart the average will be zero and no reading will result. The equation governing this is:

$$I_{meter\ (avg)} = K E \cos \theta$$

Where K = proportionality constant
E = rms of signal
θ = angle between signal and reference

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. Measurements at the quadrature null point (θ = 90 deg.) are unaffected by saturation.

When used as a standard voltmeter the phase sensitive rectifier is switched to that of a full wave rectifier. Operation is identical to that of a full wave bridge power supply in which the meter movement acts as the load.

Power Supplies

The power supply is a full wave silicon rectifier bridge type, the output of which is broken into two branches. Each of these branches is well filtered and regulated with a Zener diode.

NORTH ATLANTIC industries, inc.
terminal drive, plainview, l. i., n. y., overbrook 1-8600

SECTION V

MAINTENANCE

The following section contains instructions for the maintenance and alignment of the Phase Angle Voltmeter. It is recommended that these procedures be followed only if proper test equipment is on hand and if sufficiently skilled personnel are available to perform the work.

Cover Removal

Cover is held in place by four flat head screws on the bottom and by fourteen binder head screws, seven on each side.

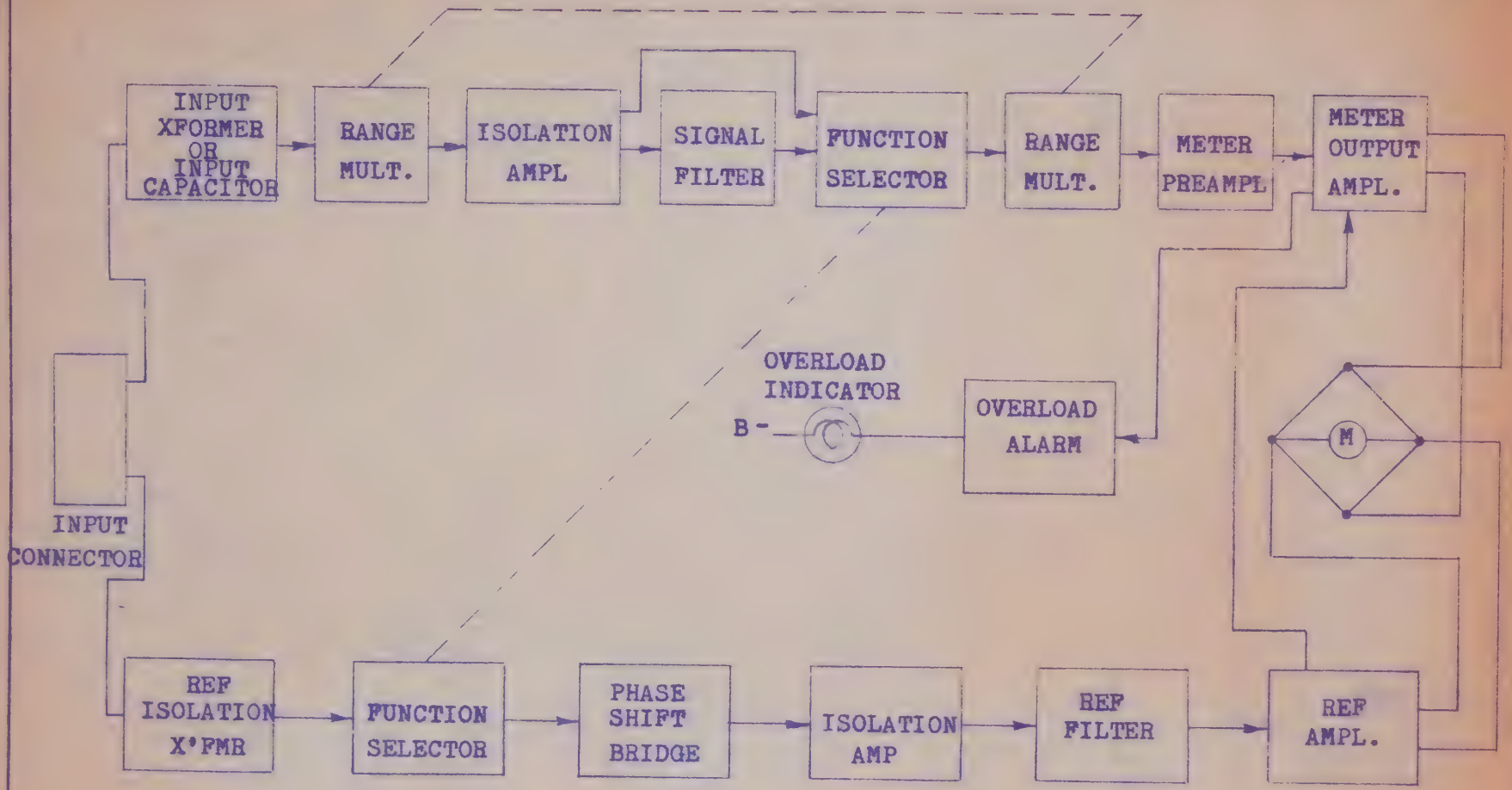
Crystal Diode & Transistor Replacement

When replacing crystal diodes or transistors, care must be taken to avoid damage to the diode through excessive heating while soldering. A simple precaution is to clip an alligator clip to the lead of the diode being soldered in place. Be sure to use a well tinned soldering iron.

Amplifier Replacement

Amplifiers normally do not have to be replaced. The amplifiers are plug-in and in the event they must be replaced, only one of the same type may be used. They are not interchangeable! They may be pulled out by first removing the amplifier hold-down bracket which is held in place by two elastic stop nuts. (These nuts should be replaced if removed).

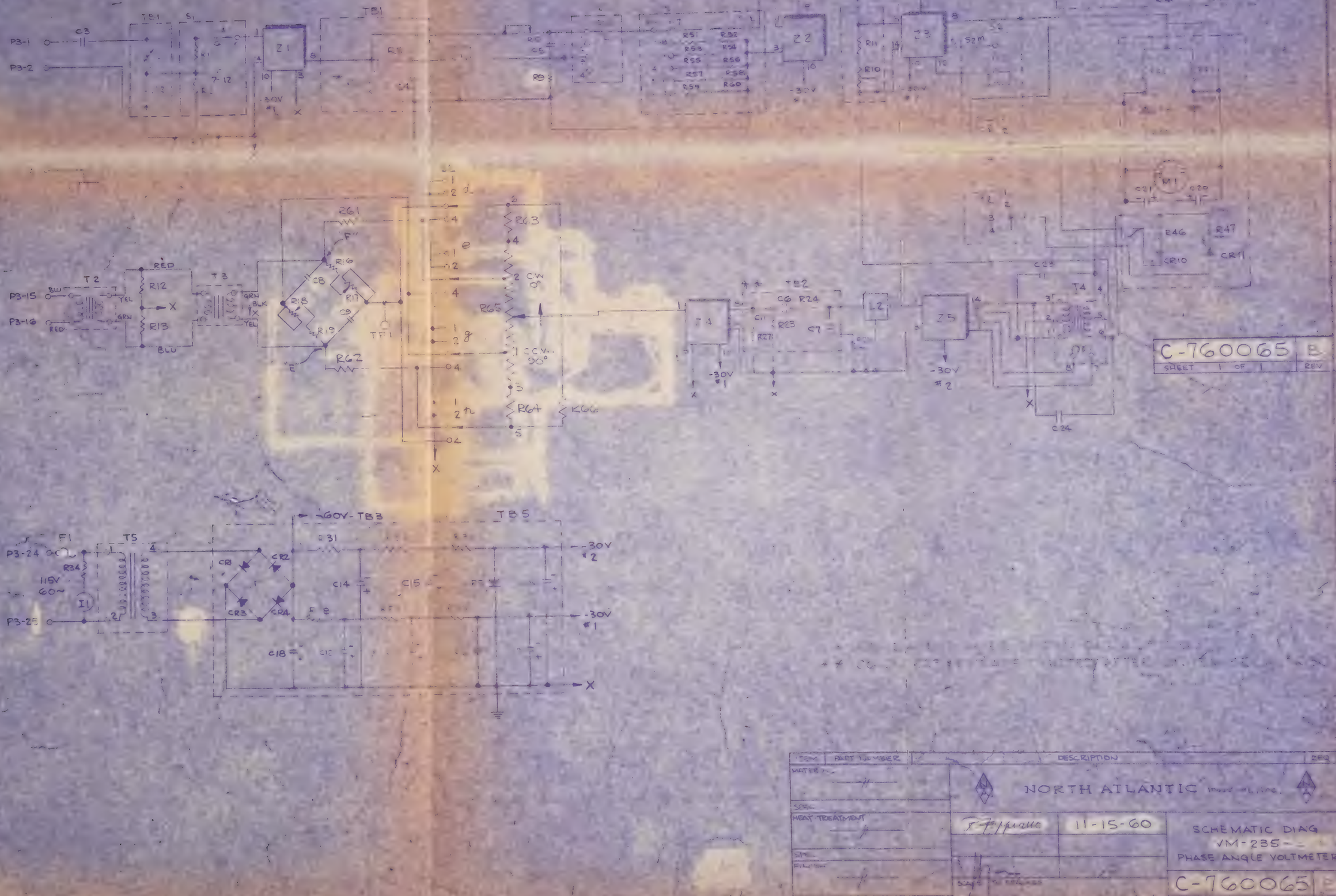
NORTH ATLANTIC industries, inc.
terminal drive, plainview, l. i., n. y., overbrook 1-8600



BLOCK DIAGRAM

FIG. 5.1

USE ON				REVISIONS				
PART NUMBER	JOB NO	CUSTOMER	CUSTOMER'S NO.	ECN # 1918	RF	5-11-62		A
		S-221		ECN # 2184	LW	2-9-64		B



ITEM	PART NUMBER	DESCRIPTION	REQ
MATERIAL			
SPEC.			
HEAT TREATMENT			
SIZE			
FINISH			

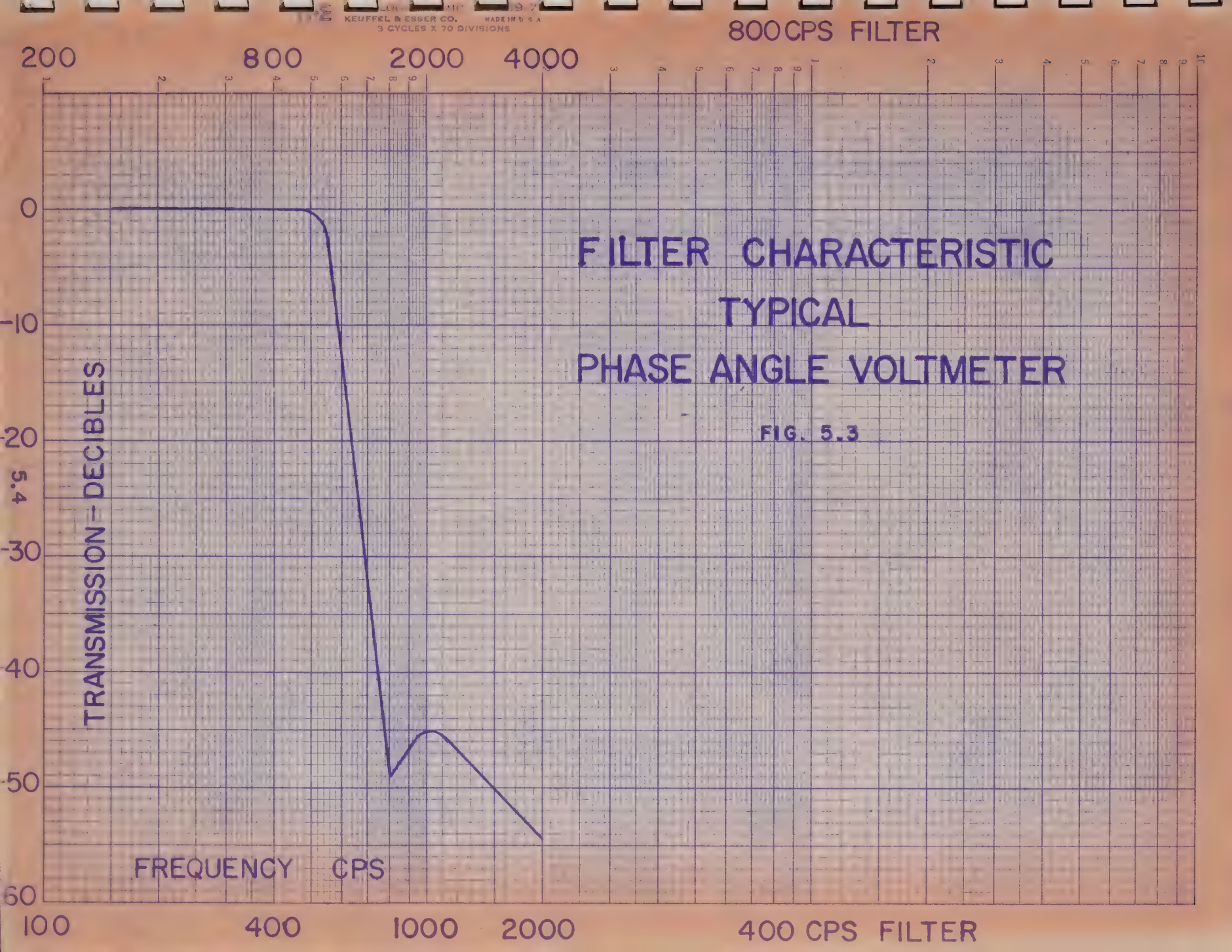
NORTH ATLANTIC INDUSTRIES, INC.

[illegible]	11-15-60

SCHEMATIC DIAG
VM-235-[illegible]
PHASE ANGLE VOLTMETER

C-760065 B

SCALE [illegible] SHEET 1 OF 1 REV


KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
800 CPS FILTER
200
800
2000
4000
0
-10
-20
-30
-40
-50
-60
TRANSMISSION - DECIBLES
FREQUENCY CPS
100
400
1000
2000
400 CPS FILTER
FILTER CHARACTERISTIC
TYPICAL
PHASE ANGLE VOLTMETER
FIG. 5.3
5.4

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

November 23, 1965
(Revised,
September 23, 1966)

Designation	Description	NAI Part No.	Manufacturer
C1a	Capacitor, Mica, 50uuf, 500V, ±5%	801685	Elmenco DM15E500J
C3	Capacitor, Paper, 1uf, 600V	800771	Aerovox P123ZN
C5	Capacitor, Mylar, .0015, 100V, ±20%	800595	Goodall 633UW
C8,C9	Capacitor, Stabilized Wax, .15uf, 200V	800939	Sprague 88P1549252
C23,C24	Capacitor, Mica, 75uuf, 500V	800912	Elmenco CM15E-750J
R1	Resistor, Dep. Carbon, 2 Meg, 1/2W, ±5%	800512	
R2	Resistor, Dep. Carbon, 1.5K, 1/2W, ±5%	800513	
R61,R62	Resistor, Fixed, Comp., 1.5K, 1/2W, ±10%	800080	
R3,R17,R18	Resistor, Variable, WW, 4K, 2W	800009	Clarostat Type 43
R6	Resistor, Variable, WW, 5K, 2W	800517	Clarostate Type 43
R9**	Resistor, Comp., 100 ohms, 1/2W, ±5%	800631	
R10	Resistor, Variable, WW, 500 ohms, 2W	800816	Clarostat Type 43
R11	Resistor, Dep. Carbon, 600 ohms, 1/2W, ±5%	800519	

** Nominal value only, factory set for optimum performance.

Designation	Description	NAI Part No.	Manufacturer
R12,R13	Resistor, Comp., 1K, 1/2W, ±5%	800414	
R16,R19	Resistor, WW, 2.2K, 1/8W, ±1% Temperature Coefficient, 20ppm/Deg. C	800791	
R25	Resistor, Variable, WW, 50K, 2W	801269	Clarostat Type 43
R34	Resistor, Comp., 68K, 1/2W, ±5%	800528	
R49	Resistor, WW, 4.28K, 1/8W, 1/4%	800824	
R50	Resistor, WW, 13.33K, 1/8W, 1/4%	800825	
R61,R62	Resistor, Comp., 1.5K, 1/2W, ±10%	800080	
R63,R64	Resistor, Dep. Carbon, 39K, 1/2W, ±1%	800067	
R65	Resistor, Variable, WW, 50K, Tapped Special	117-2.000-39	
Z1,Z4	Amplifier Assembly, Isolation	D-782013	
Z2	Amplifier Assembly, Meter Preamplifier	D-782035	
Z3	Amplifier Assembly, Meter Output Amp.	D-782014	
Z5	Amplifier Assembly, Reference	D-782015	
M1	Meter	B-800326	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y.
OVerbrook 1-8600
5.6
9/23/66

Designation	Description	NAI Part No.	Manufacturer
XF1	Fuseholder, 3AG	800117	Littelfuse, #342001
F1	Fuse, .25 amperes, 3AG, 250V	802530	
I1	NE2J Pilot Lamp	800532	
I2	#344 Overload Lamp	800533	
XI1	Lampholder, Pilot	800397	Dialco No. 137-7236-931 (Red)
XI2	Lampholder, Overload	800396	Dialco No. 101-3830-397 (Clear)
P3	Connector	800328	Amphenol #26-159-32
S1	Range Switch Assembly	800010	
R1	Resistor, Fixed, D.C., 2 Meg, 1/2W, ±5%	800512	
R2	Resistor, Fixed, D.C., 1.5K, 1/2W, ±5%	800513	
R51	Resistor, Fixed, 6.84K, 1/8W, 1/4%	800794	General Resistance #HA04
R52	Resistor, Fixed, 4.63K, 1/8W	800793	General Resistance #HA04

Designation	Description	NAI Part No.	Manufacturer
R53	Resistor, Fixed, 9K	800796	General Resistance #HA04
R54	Resistor, Fixed, 1.111K	800790	General Resistance #HA04
R55	Resistor, Fixed, 9.68K	800795	General Resistance #HA04
R56	Resistor, Fixed, 327	800789	General Resistance #HA04
R57	Resistor, Fixed, 9.9K	800797	General Resistance #HA04
R58	Resistor, Fixed, 101	800788	General Resistance #HA04
R59	Resistor, Fixed, 9.97K	800798	General Resistance #HA04
R60	Resistor, Fixed, 31.7Ω, 1/8W, 1/4%	800787	General Resistance #HA04

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y.
CYpress 1-8600

Designation	Description	NAI Part No.	Manufacturer
S2	Function Switch Assembly	500302	
S3	Switch, Toggle, Miniature	800535	Micro Switch 6AT2
J1,J2,J3,J4, J5	Connector, 15 Pin Female	800582	Cannon DA15-S
	Phase Dial Assembly	B-500104	
	Indicator	B-200337	
	Knob (Pointer)	800337	M.S. #91528-1P2D
T2	Transformer, Input, Reference	800536	UTC 0-16
T3	Transformer, Driver, Reference	800537	UTC DO-T 10
T4	Transformer, Driver, Bridge	800370	
T5	Transformer, Power	800372	
L1.L2	Filter	B117-2.000-21	

REPLACEMENT PARTS LIST (Cont'd)

Designation	Description	NAI Part No.	Manufacturer
TB1			
Consists of:	Terminal Board Assembly	500054	
C1	Capacitor, Ceramic, Variable, 7-45uuf	800040	Erie 503000-D2P0-33K
C2	Capacitor, Paper, .075uf, 100V, ±10%	801725	Sprague 91P75351S4
C4	Capacitor, Paper, .01uf, 400V, ±20%	800019	Sprague 160P10304
R5	Resistor, Dep. Carbon, 10K, 1/2W, ±5%	800516	
R8***	Resistor, Fixed, 30K, 1/2W, ±5%	800622	
TB2			
Consists of:	Terminal Board Assembly	500055	
C7	Capacitor, Paper, .022uf, 400V	800503	Sprague 150P22304
R24	Resistor, Dep. Carbon, 10K, 1/2W, ±5%	800516	

*** Added after Serial No. 1030

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y.
OYsterbook 1-8600

Designation	Description	NAI Part No.	Manufacturer
TB3 Consists of:	Overload Circuit Board Assembly	500052	
C9	Capacitor, Tantalum, 60uf, 6V	800511	Sprague 150D606X0006B2
C22	Capacitor, Tantalum, 47uf, 50V	800504	Sprague 109D476X0050F2
R35	Resistor, Comp., 24K, 1/2W, ±5%	800518	
R36	Resistor, Comp., 100K, 1/2W, ±5%	800520	
R37	Resistor, Comp., 22K, 1/2W, ±5%	800635	
R38	Resistor, Comp., 12K, 1/2W, ±5%	800644	
R39	Resistor, WW, 1.2K, 2W, ±5%	801819	Sprague 240E1225
R40	Resistor, Comp., 30 ohms, 1/2W, ±5%	801146	
R41**	Resistor, Comp., 30 ohms, 1/2W. ±5%	801146	
R48	Resistor, Comp., 1.2K, 2W, ±5%	800785	
CR7	Silicon Diode Type #1N645	800323	
CR12	Silicon Diode	800778	Transitron Type SG22
Q1,Q2	Germanium Transistor Type 2N1229	801813	

** Nominal value only. Factory set for optimum performance.

NORTH ATLANTIC industries, inc. 5,11 9/23/66
200 terminal drive, plainview, n.y. (516) ohook 1-8600

Designation	Description	NAI Part No.	Manufacturer
	In instruments preceding Serial No. 5787, TB3 consisted of the following components. In the event parts must be replaced, it is recommended that all components required to modify this circuit to the latest, improved version be included.		
C19	Capacitor, Tantalum	800511	Sprague 150D106X0015B2
C22	Capacitor, Tantalum, 47uf, 50V, ±20%	800504	Sprague 109D476X0050F2
R35	Resistor, Comp., 24K, 1/2W, ±5%	800518	
R36	Resistor, Comp., 100K, 1/2W, ±5%	800520	
R37	Resistor, Comp., 68K, 1/2W, ±5%	800528	
R38	Resistor, Comp., 20K, 1/2W, ±5%	800521	
R39	Resistor, Comp., 1.2K, 1/2W, ±5%	800522	
R40, R41**	Resistor, Comp., 51 ohms, 1/2W, ±5%	800523	
R48	Resistor, Comp., 1.2K, 2W, ±5%	800785	

** Nominal value only, factory set for optimum performance.

NORTH ATLANTIC industries, inc.
200 terminal drive plainview, n. y. (Overbrook 1-8800)

Designation	Description	NAI Part No.	Manufacturer
CR7	Silicon Diode, Type 1N645	800323	
CR12	Silicon Diode	800778	Transitron Type #SG22
Q1,Q2	Germanium Transistor, Type 2N526	800652	

Designation	Description	NAI Part No.	Manufacturer
TB4 Consists of:	Meter Circuit Board Assembly	500125	
C20,C21	Capacitor, Tantalum, 60uf, 6V	800511	Sprague 150D606X0006B2
R42,R43	Resistor, Comp., 2.4K, 1/2W, ±5%	800529	
R44,R45,R46, R47	Resistor, Comp., 510 ohms, 1/2W, ±5%	800525	
CR8,CR9, CR10,CR11	Silicon Diode	801661	Clevite 1N658
TB5 Consists of:	Power Supply Board Assembly	C-500053	
C12,C13,C14, C15	Capacitor, Tantalum, 40uf, 75V	800507	Sprague 109D406C7075T2
C16,C17	Capacitor, Tantalum, 10uf, 50V	800508	Sprague 109D106X0050C2
C18	Capacitor, Tantalum, 30uf, 100V	800509	Sprague 109D306C7100T2
R28,R29,R30	Resistor, Comp., 330 ohms, 1W, ±5%	800527	

Designation	Description	NAI Part No.	Manufacturer
R31,R33	Resistor, Comp., 270 ohns, 1/2W, ±5%	800642	
R32	Resistor, Comp., 300 ohns, 1/2W, ±5%	800683	
CR1,CR2, CR3,CR4	Silicon Diode Type 1N645	800323	
CR5,CR6	Silicon Diode, 30V, Zener, 1.5W	800530	

SECTION VI

CALIBRATION TEST PROCEDURE

The adjustments described in this section require precision test equipment in order to achieve rated accuracy. It is recommended the instrument be returned to the factory or submitted to your instrument calibration laboratory if recalibration is required.

The following detailed calibration and alignment procedures are presented to assist a qualified technician in properly recalibrating the Model VM-235. Caution is required to avoid errors due to ground loops. (Refer to application notes on ground loops for full information prior to proceeding with calibration.)

EQUIPMENT REQUIRED

1. 115 volt Signal Source capable of generating reference frequency for the Model VM-235 under test. Accuracy of frequency of the Signal Source should be ±1/2%.

2. AC Voltmeter with ±3/4% full scale accuracy or better, (eg., Sensitive Research Corp. Model U-88 Poly-Ranger).

3. AC Vacuum Tube Voltmeter (eg., Hewlett-Packard Model 400D).

4. Two (2) North Atlantic Industries Model RB-503 Ratio Boxes.

5. Ohmmeter (eg., Simpson Model 360 Multimeter).

6. Capacitors and Resistors as described in PHASE BRIDGE ALIGNMENT, Page 6.4.

VOLTAGE CALIBRATION

1. Connect Instrumentation as shown in Fig. 6.2.1 Connection #A.

2. Front panel must remain vertical during all the following procedures and cover must be removed. Set to "300" volt Range, turn on external power switch and allow 5-minute warmup.

3. Adjust output of Ratio Box #1 to 10.00 volts and monitor with AC Voltmeter.

4. Set "FUNCTION" Selector to "FUND".

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

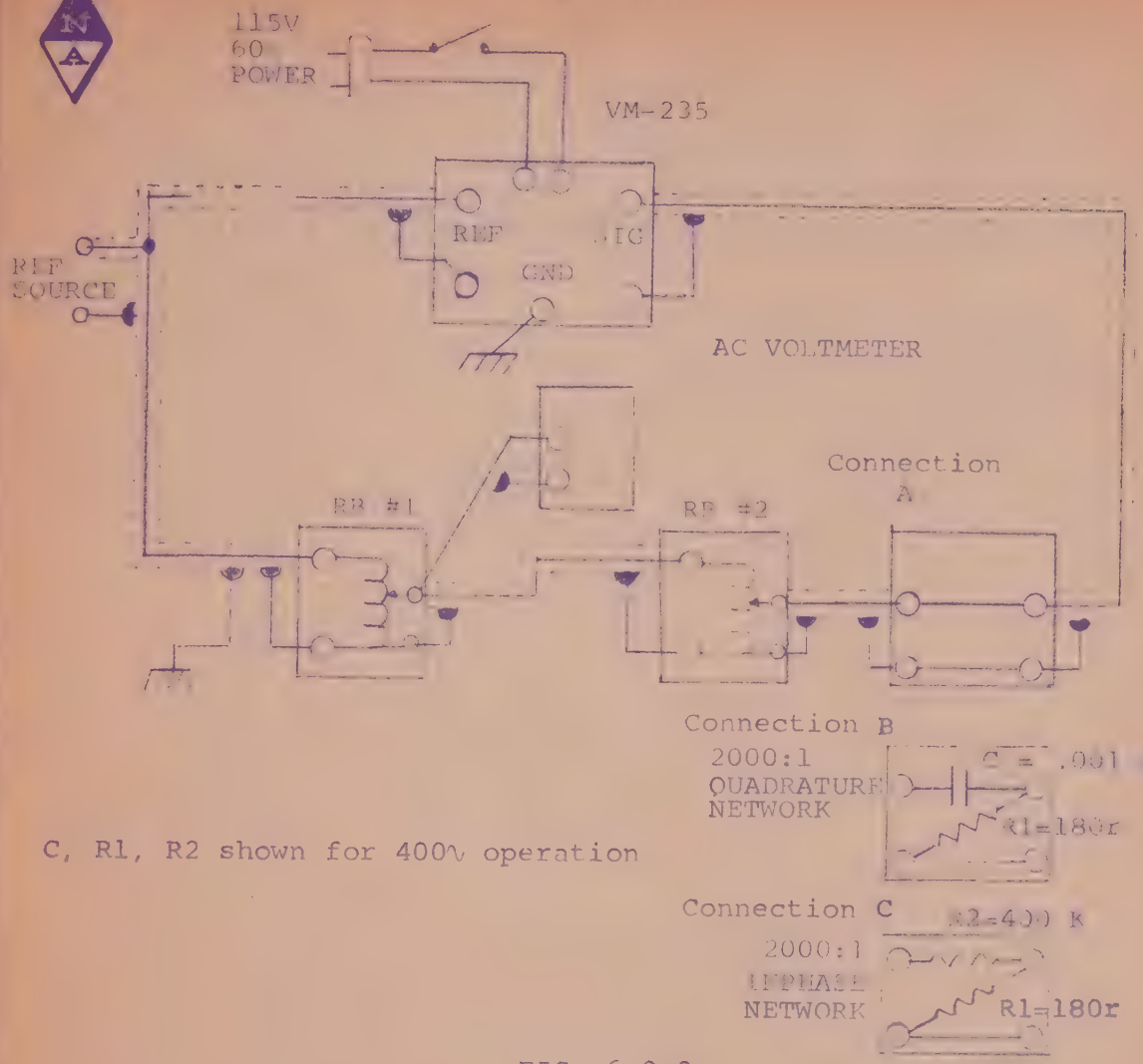


FIG. 6.2.2

NORTH ATLANTIC industries inc.
terminal data

5. Set "RANGE" Selector to "0.1" volts.

6. Set Ratio Box #2 to setting of .010000 (output of 0.1 volts).

7. Adjust "R10" (Fundamental Calibrate Pot located on right side of chassis, see Page 6.7), until Meter reads exactly full scale. Lock jam nut on "R10".

8. Switch "FUNCTION" Selector to "TOTAL" and adjust "R6" (Total Calibrate Pot located on left side of chassis, see Page 6.7), for exactly full scale reading. Lock jam nut on "R6".

"DEGREES" PHASE DIAL ALIGNMENT

This test is a verification of factory alignment of the "DEGREES" phase dial to the phase shifter pot "R65". Adjustment should not normally be required, but alignment procedure is as follows:-

1. Turn external power switch off.

2. Set "FUNCTION" Selector to either phase sensitive position (i.e., "0°" or "90°").

3. Connect the Ohmmeter between the wiper of "R65" and the CCW tap point and rotate "DEGREES" phase dial for minimum resistance reading. Loosen "DEGREES" phase dial clamping screw and shift "DEGREES" phase dial until dial reading is exactly "90°". Tighten clamping screw. Connect Ohmmeter between the wiper of "R65" and the CW tap point and rotate "DEGREES" phase dial until wiper of "R65" is on CW tap point (minimum resistance reading). The "DEGREES" phase dial should now read "0°". If not, note the difference and reposition dial so as to achieve the best compromise reading between the two taps. (eg., if the "0°" point reads low, the "90°" point should read high by the same amount. Fully tighten knob set screw and recheck to make sure "DEGREES" phase dial has not slipped during tightening.)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

PHASE BRIDGE ALIGNMENT

Additional Equipment Required

Capacitor C (eg., mica or polystyrene for low loss and maximum stability).

Composition Resistor (±5%) R1.

Metal Film Resistor (±5%) R2 (eg., non-reactive).

These components are to establish a precision 90° phase shift to provide a quadrature test voltage. For ease of description, components for 400∿ are shown in the block diagram. For VM-235's with other reference frequencies, C & R1 are determined based upon at least a 2000:1 attenuator,

i.e., $C = \frac{1}{2\pi f X_C}$

$X_C = 2000\ R1$

$R2 = X_C$

Procedure

Connect the 115v Signal Source, Capacitor C and Composition Resistor R1 as shown in Fig. 6.2.1 Connection #B.

1. Signal across R1 should be approximately 50mv. This is the amplitude of the quadrature test voltage.

2. Turn on external power switch. Allow 5-minute warmup before proceeding with PHASE BRIDGE ALIGNMENT.

3. Set "FUNCTION" Selector to "0°" position. (Position of "DEGREES" phase dial is not critical, and it may be arbitrarily set to any position.)

4. With AC VTVM measure voltage across "C9" (between terminal E and Test Point "TP1" of Fig. 6.7). Record reading. Measure total voltage across "R16" in series with "R17" (between terminal F and Test Point "TP1" of Fig. 6.7). Record reading. These voltages should be balanced to within .05 volts of each other by adjusting "R17". NOTE: Be sure high side of AC VTVM is connected to Test Point "TP1" to avoid common mode error. (See schematic.)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

5. Set "FUNCTION" Selector to "0°", "DEGREES" phase dial to "0°", and "RANGE" Switch to ".01" volts.

6. Adjust "R25" until meter reads zero. (This test is run with a 50mv quadrature signal on the 10mv range, i.e., 5:1 overload.)

7. Remove Capacitor C and replace with Metal Film Resistor R2, as in Fig. 6.2.1 Connection #C. (The test signal is now of approximately equal magnitude, but is in-phase instead of quadrature.)

8. Set "FUNCTION" Selector to "90°". (Keep "DEGREES" phase dial to "0°" and "RANGE" Switch to ".01" volts.)

9. Adjust "R18" until meter reads zero. (This test is run with a 50mv in-phase signal on the 10mv range, i.e., 5:1 overload.)

10. Remove Metal Film Resistor R2 and replace with Capacitor C, as in Fig. 6.2.1 Connection #B. Set "DEGREES" phase dial to "90°". (Keep "FUNCTION" Selector at "90°" and "RANGE" Switch at ".01" volts.) Check for zero meter reading.

11. Repeat Steps 5 through 10 until all readings are as near to zero as possible.

12. Lock jam nuts "R17", "R18" and "R25".

13. Recheck Steps 5 through 10 to be sure jam nuts did not upset calibration.

14. Turn off external power switch.

INPUT ATTENUATOR ADJUSTMENT

1. Reconnect as in Fig. 6.2.1 Connection #A.

2. Set "FUNCTION" Selector to "90°", "DEGREES" phase dial to "0°" and "RANGE" Switch to "10" volts.

3. Turn on external power switch and allow 5-minute warmup.

4. Set Ratio Box #1 to provide 100 volts output as read on AC Voltmeter.

5. Set Ratio Box #2 to .500000 setting to provide 50 volts output.

6. Record meter reading (initial reading). Adjust "C1" (trimmer capacitor on bottom of chassis, accessible through small hole in internal cover, see Page 6.7), until needle moves approximately half the number of scale divisions between the initial reading and zero.

7. Reset output of Ratio Box #2 to .100000 to provide 10 volts output.

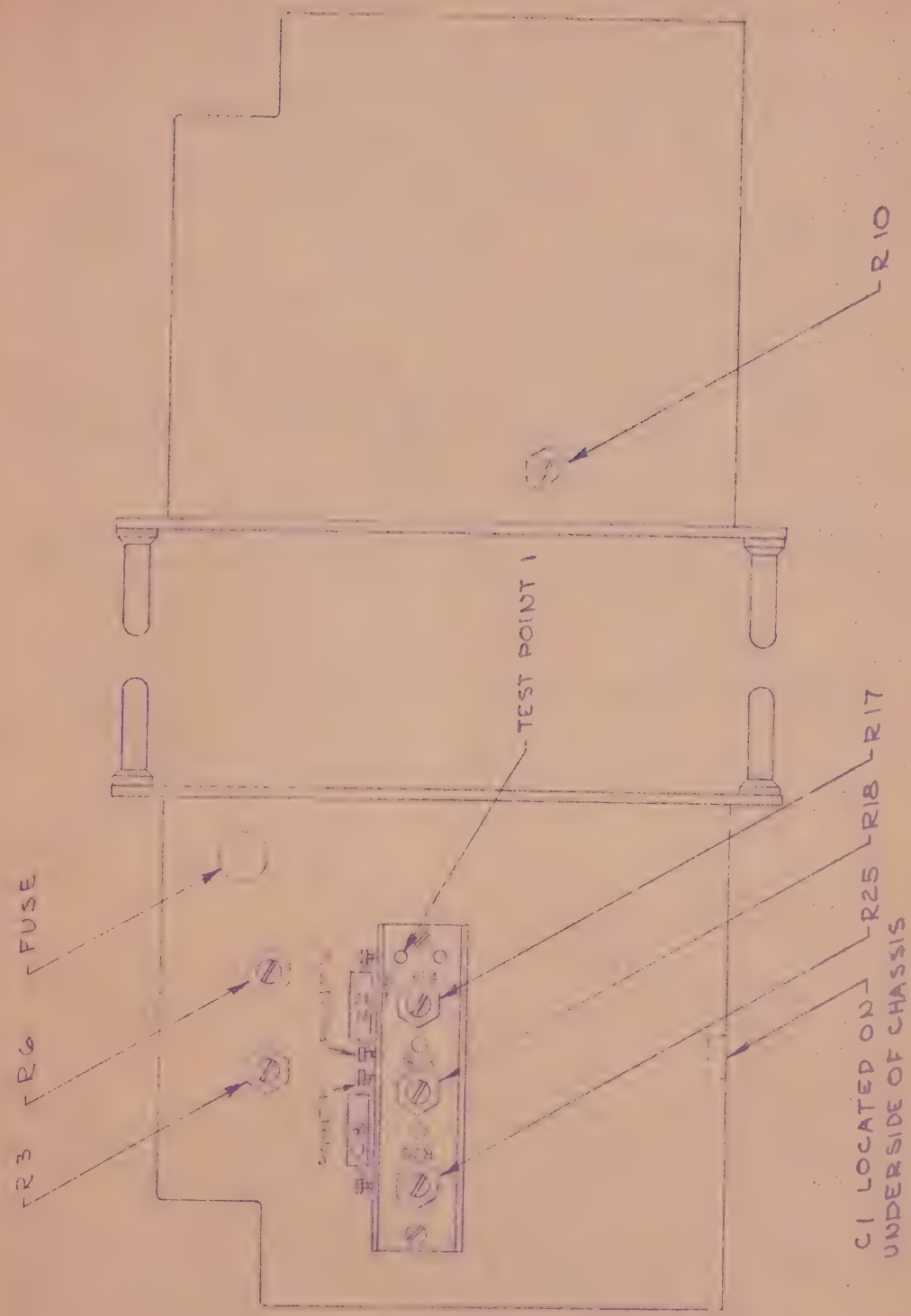
8. Set "FUNCTION" Selector to "FUND".

9. Record meter reading (initial reading). Adjust "R3" (located on left side of chassis, see Page 6.7), until meter pointer moves half the number of divisions between initial reading and full scale.

Repeat Steps 2 through 9 until meter reads exactly zero when "FUNCTION" Selector is in "90°" position and exactly full scale when "FUNCTION" Selector is in "FUND" position.

NOTE: There is considerable interaction between "R3" and "C1" and several adjustments may have to be made to set these controls to their correct positions. Lock "R3" and glyptal "C1" when this alignment is complete.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600



NORTH ATLANTIC *industries, inc.*
terminal drive, plainview, l. i., n. y., overbrook 1-8600

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

WARRANTY

North Atlantic Industries, Inc. warrants its products against defects in material and workmanship for one year from the date of the original shipment. Our liability is limited to repairing or replacing products (except fuses and electron tubes) which prove to be defective during the warranty period.

North Atlantic Industries, Inc. is not liable for consequential damages or for any damage or injury to persons or property resulting from the operation or application of any of its equipment.

Warranty is voided if there is evidence that the product has been operated beyond its design range, improperly maintained, or physically mistreated.

In the event of a malfunction in a product under warranty, the purchaser should notify his local Sales Representative or the Sales Department of North Atlantic Industries, Inc. giving full details of the defect and providing the model and serial number of the instrument. Service data or shipping instructions will be forwarded promptly. There is no charge for warranty repair of products, except transportation charges.

North Atlantic Industries, Inc. reserves the right to make changes and improvements in its products without any liability for incorporating such changes or improvements in any products previously sold.

No other warranty expressed or implied is offered other than the foregoing.

Estimates of charges for out of warranty repairs or other service work will be supplied before work begins. Out of warranty repairs will only be made following the receipt of purchaser's authorization of applicable charges.

Claims for Damage in Shipment

The purchaser should inspect and functionally test the product in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

(turn over for Shipping Instructions)

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Shipping

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

SALES REPRESENTATIVES

ALABAMA
FACT-TRONICS
Huntsville: 205-539-7193

CALIFORNIA
INSTRUMENT SPECIALISTS
Los Angeles: 213-665-5181
Sunnyvale: 408-245-3321

CONNECTICUT
BROGAN ASSOCIATES, INC.
(Westbury, N.Y.): 516-333-6684

FLORIDA
FACT-TRONICS
Casselberry: 305-838-5607

GEORGIA
FACT-TRONICS
Atlanta: 404-525-2434

ILLINOIS
PAT LIND ELECTRONICS CO.
Chicago: 312-774-1246

INDIANA
PAT LIND ELECTRONICS CO.
Indianapolis: Enterprise 7711

KANSAS
TECHNICAL REPRESENTATIVES, INC.
Olathe: 913-782-3775
Wichita: 316-682-4140

MARYLAND
RON DAVIES ASSOCIATES
Bethesda: 301-652-6330

MASSACHUSETTS
BROGAN ASSOCIATES, INC.
Waltham: 617-894-3250
Pittsfield: (Totowa, N.J.) 201-256-0174

MICHIGAN
WKM ASSOCIATES
Detroit: 313-892-2500

MINNESOTA
PAT LIND ELECTRONICS CO.
Circle Pines: 612-781-6568

MISSOURI
TECHNICAL REPRESENTATIVES, INC.
Hazelwood: 314-521-1000

NEW YORK
BROGAN ASSOCIATES, INC.
Rochester: 716-328-2350
Syracuse: 315-437-2988
NORTH ATLANTIC INDUSTRIES, INC.
Plainview: 516-681-8600

OHIO
WKM ASSOCIATES
Cleveland: 216-885-5616
Dayton: 513-298-7203

PENNSYLVANIA
ACROMATIX ASSOCIATES, INC.
Fairview Village: 215-279-0377
WKM ASSOCIATES
Pittsburgh: 412-892-2953

TEXAS
SCIENTIFIC SALES CO.
Richardson: 214-231-6541
Houston: 713-528-6904

WASHINGTON
WESTERN ELECTRO DYNAMICS CO.
Seattle: 206-682-8412

WISCONSIN
PAT LIND ELECTRONICS CO.
Milwaukee: Enterprise 1611

FOREIGN SALES

Canada
ELECTROMECHANICAL PRODUCTS
Agincourt, Ontario: 416-293-7011

Belgium
C. N. ROOD, N.V.
Brussels: 02-35.54.79

Denmark*
TECHNITRON
Copenhagen: Palae 2632

France*
TECHNITRON
Paris: 359 44-33

Germany
NUCLETRON VERTRIEBS GmBH
Munchen: (0811) 546081
Cologne-Heimersdorf
Hamburg: (0411) 450190

Holland
C. N. ROOD, N.V.
Rijswijk: The Hague 98.51.53

Israel
RACOM ELECTRONICS CO.
Tel-Aviv: 443244

Sweden
AJGERS ELECTRONIK AB
Stockholm: 08/46 42 46

Switzerland
NUCLETRON AG
Bern: 031 3 74 51

United Kingdom
AVELEY ELECTRIC, LTD.
South Ockendon: 3444

All Other Countries
Contact Factory, Cable: NOATLANTIC

*New York Office: Columbia Commerce Corp.: 212-758-2790

COMPONENTS

New York
BASSIN TECHNICAL SALES CO.
Yonkers, N.Y.: 914-237-0173

6/67

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

WARRANTY REGISTRATION

Please complete and mail this Warranty Registration Card without delay. Placing this Registration on file with our Service Department will assure that you receive applicable service data as issued. No postage is required.
(Mailed on_____ by_____)

WARRANTY REGISTRATION

Date _____

Please register _____
Model No. _____ Serial No. _____
under the terms of the warranty stated in this Instruction Manual.
Name _____
Title _____ Dept. _____
Company _____
Address _____
City _____ State _____ ZIP _____
Calibration and maintenance responsibility has been assigned to the following person and/or department. Address applicable service data to (if same as above, please state):
Name _____
Title _____ Dept. _____
For our information please indicate:
Condition of instrument on receipt _____
Application _____
Will the instrument be: resold as part of a system? _____
maintained as company equipment? _____

SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

SERVICE INFORMATION REQUEST

Instrument _____
Model No. _____ Serial No. _____
We require the following service information: _____

Name _____ Title _____
Company _____ Dept. _____
Address _____
City _____ State _____ ZIP _____
Phone _____ Ext. _____

SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

SERVICE INFORMATION REQUEST

Instrument _____
Model No. _____ Serial No. _____
We require the following service information: _____

Name _____ Title _____
Company _____ Dept. _____
Address _____
City _____ State _____ ZIP _____
Phone _____ Ext. _____
(please send additional Service Information Request cards _____)

No Postage Stamp Necessary If Mailed in the United States

Postage Will be Paid by Addressee

BUSINESS REPLY MAIL

First Class Permit No. 505, Sec. 34.9, P.L.&R. Hicksville, L. I., N. Y.

NORTH ATLANTIC
industries, inc.

200 TERMINAL DRIVE,

PLAINVIEW, N. Y. 11803

No Postage Stamp Necessary If Mailed in the United States

Postage Will be Paid by Addressee

BUSINESS REPLY MAIL

First Class Permit No. 505, Sec. 34.9, P.L.&R. Hicksville, L. I., N. Y.

NORTH ATLANTIC
industries, inc.

200 TERMINAL DRIVE,

PLAINVIEW, N. Y. 11803

No Postage Stamp Necessary If Mailed in the United States

Postage Will be Paid by Addressee

BUSINESS REPLY MAIL

First Class Permit No. 505, Sec. 34.9, P.L.&R. Hicksville, L. I., N. Y.

NORTH ATLANTIC
industries, inc.

200 TERMINAL DRIVE,

PLAINVIEW, N. Y. 11803

APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter, and a power factor meter.

Copyright 1957, 1966 by North Atlantic Industries, Inc.
All Rights Reserved
Printed in U.S.A.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

TABLE OF CONTENTS

		Page
I.	Introduction	1
II.	General Notes on Grounding Techniques	2
III.	Phase Characteristic	6
	1. Response to Harmonics	
	2. Accurate Phase Measurements	
IV.	Phase Angle Measurement Using Phase Shifter	11
V.	Measurement of In-Phase and Quadrature Components	12
VI.	Measurement of Power Factor and Impedance Angle	12
VII.	Measurement of Impedance	13
VIII.	Applications	15
	1. Precision Ratiometer	15
	2. Transducer Nulling	16
	3. Synchro Bridge Null Detector	17
	4. Magnetic Amplifier and Thyratron Circuit Alignment	18
	5. Carrier Circuits and Amplifier	18
	6. Transformation Ratio	19
	7. Small Angle Measurements	22

I - INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instrument's ability to measure the two basic characteristics of any signal; namely, magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure (1).

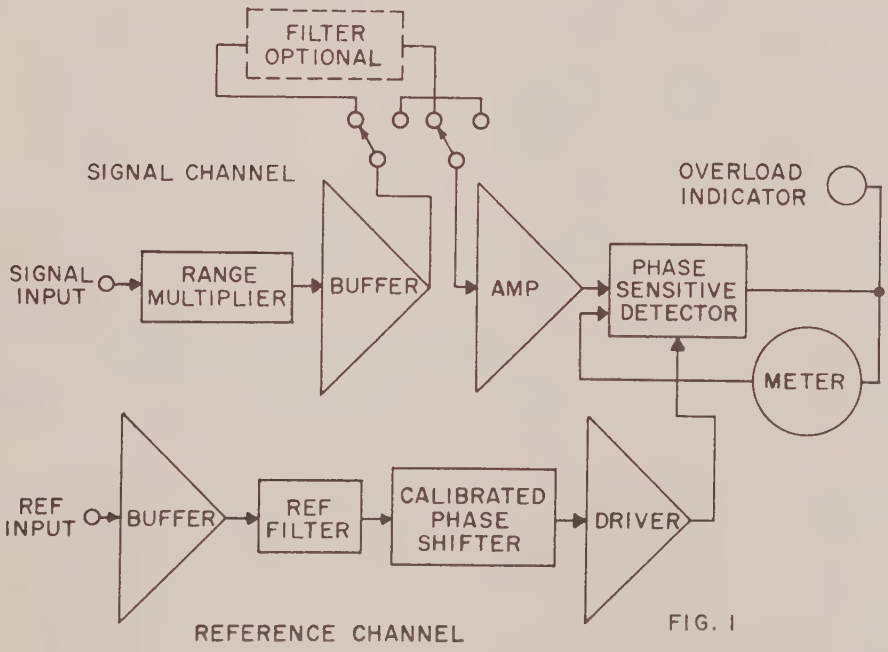


FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an AC signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures (5) and (6).

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II - GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

a) Internal noise
b) Electrostatic pickup
c) Inductive pickup
d) Common ground runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

Electrostatic pickup, frequency a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads one of which is at ground potential. Care must be taken, however, to avoid loading the signal source by the cable capacitance.

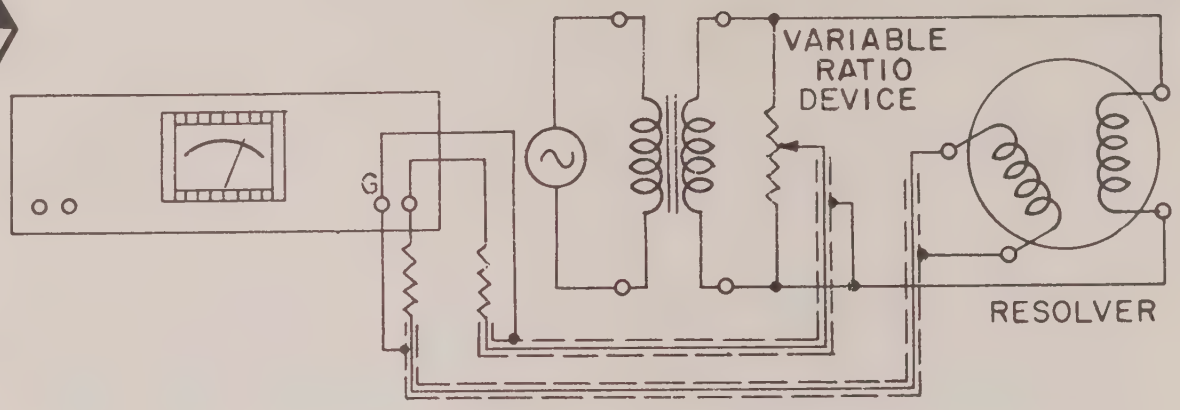
Inductive pickup is generally less often encountered than electrostatic pickup and possibly for that reason, methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that

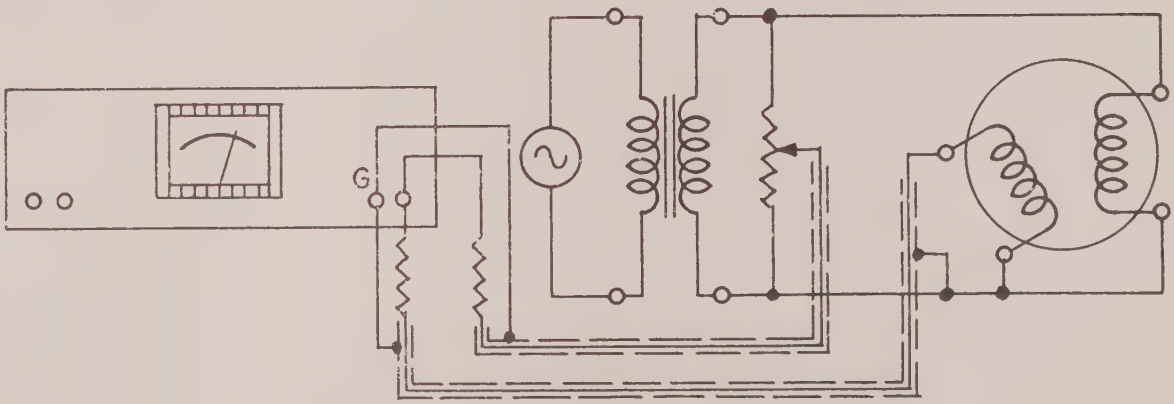
NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

portion of a circuit where a measurement is being made. Figure (2) shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure (2A) is the most advantageous arrangement and is not at all critical to lead runs. Figures (2B) and (2C) both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure (2) can exist due to chassis contact, line cord ground, and reference grounds. All must be considered when setting up the measuring system.

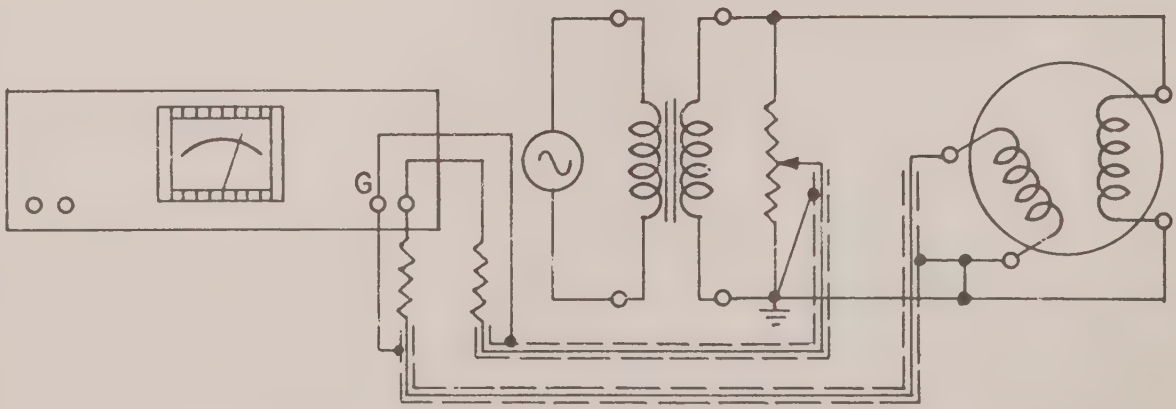
NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600



(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Common ground runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure (3) is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure (3) also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

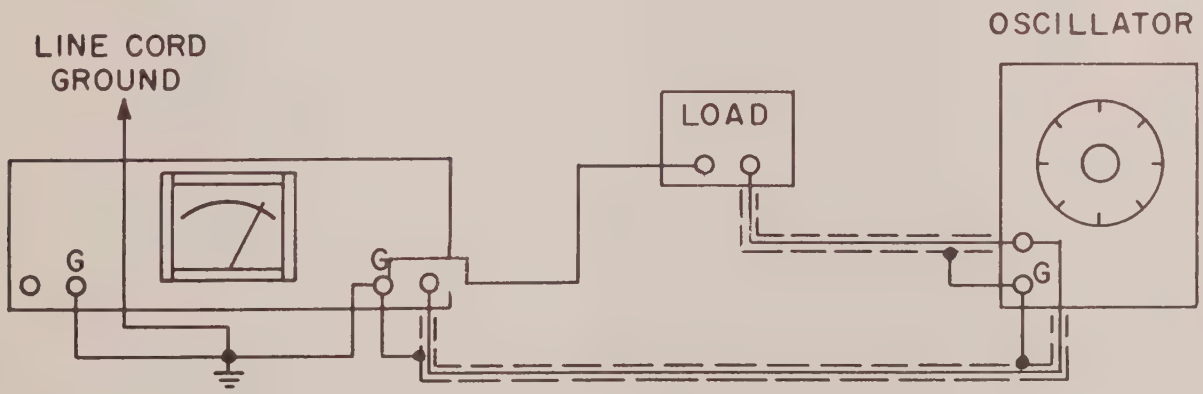


FIG. 3

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

III - PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter
E_{rms} = rms value of the input sine wave
θ = angle between the reference and signal input (Phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

(2) $$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55DB down. Table I shows typical measured responses. The values shown with filters actually are the sum of the colum I data and the filter characteristic.

TABLE I

FUND (400cps)	No Signal Filter 0DB	With Signal Filter 0DB
2nd Har.	-55DB	-55DB
3rd Har.	-9.5DB	-55DB
4th Har.	-55DB	-55DB
5th Har.	-14DB	-55DB

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the setup dhown in Figure (4). The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the θ = 90 deg. and the θ = 0 deg. point. Measurement than will be a voltage which can be directly translated into degrees using the curves of Figures (5) and (6).

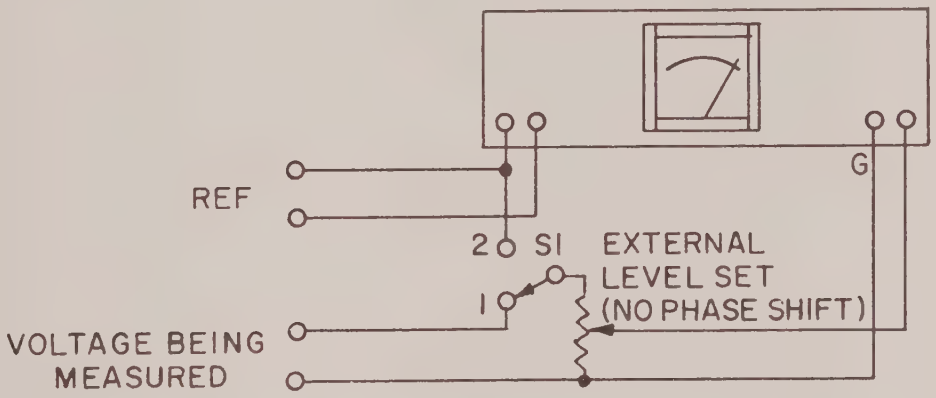


FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (NOTE: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.)

3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the θ = 0 deg. point or quadrature null point.

NOTE: FOR MAXIMUM ACCURACY, THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

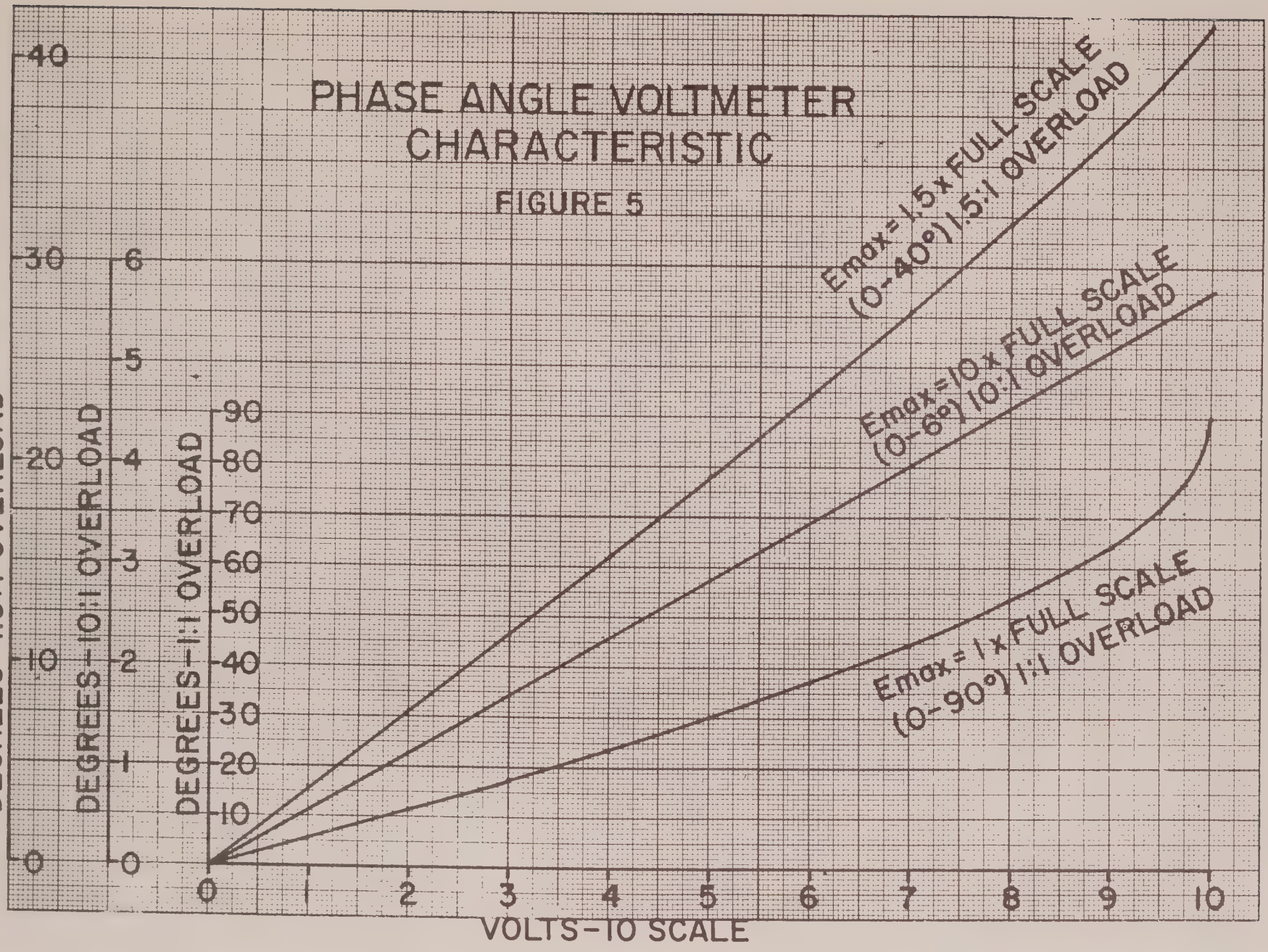
4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the θ = 90 deg. point (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure (5) or (6) to read degrees.

Any full scale range in degrees can be used even down to -6 deg. - 0 - +6 deg, depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4deg. - 0 - +17.4 deg. Table II summarizes typical setups and Figures (5) and (6) show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously, this condition is a function of reference level and for that reason, a level of twice the red line value is recommended when using this technique.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600


PHASE ANGLE VOLTMETER CHARACTERISTIC
FIGURE 5
Emax=1.5 x FULL SCALE (0-40°) 1.5:1 OVERLOAD
Emax=10 x FULL SCALE (0-6°) 10:1 OVERLOAD
Emax=1 x FULL SCALE (0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE
0
10
20
30
40
1
2
3
4
5
6
7
8
9
10
60
70
80
90
50

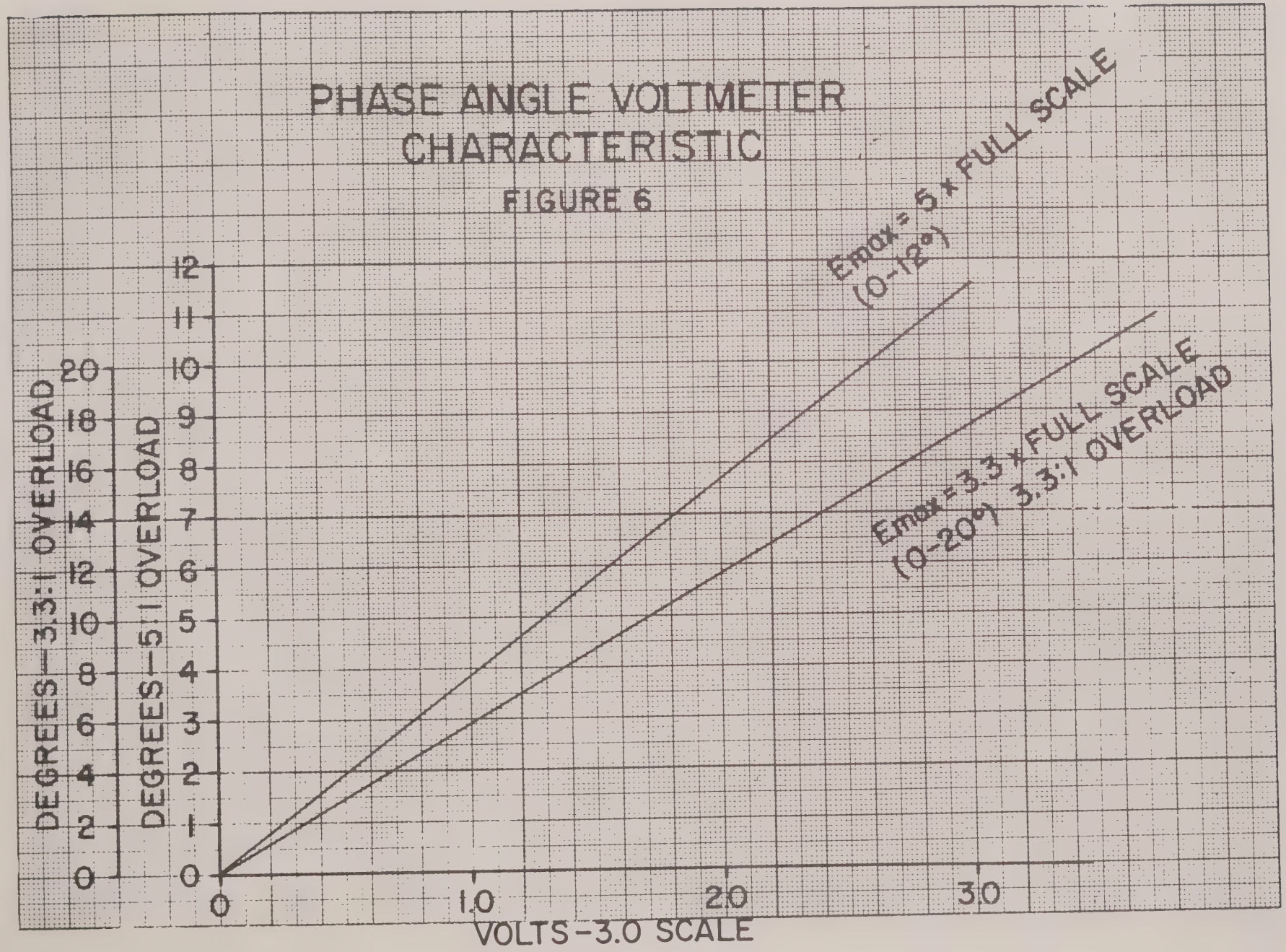

PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES—3.3:1 OVERLOAD
DEGREES—5:1 OVERLOAD
0
2
4
6
8
10
12
16
18
20
1
3
5
7
9
11
1.0
2.0
3.0
VOLTS-3.0 SCALE

TABLE II

Maximum Voltage	Scale for Measuring Degrees	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	90	2.7 deg.	5
1.0	.3	3.3:1	19.5	0.6	6
1.0	.1	10:1*	5.7	.2*	5
1.5	1.0	1.5:1	41.8	1.3	5
1.5	.3	5:1	11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV - PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built-in, calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees, the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V - MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

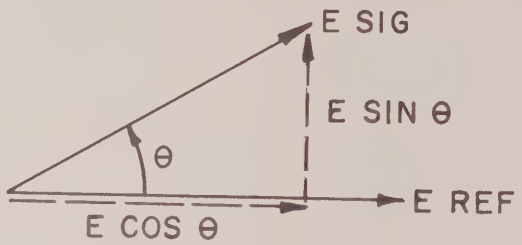


FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure (7) as:

In-phase component = E cos θ

Quadrature component = E sin θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin θ. For the greatest accuracy in this type of measurement, the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI - MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This

measurement is conveniently accomplished by means of the set up shown in Figure (8). The angle is measured as previously discussed.

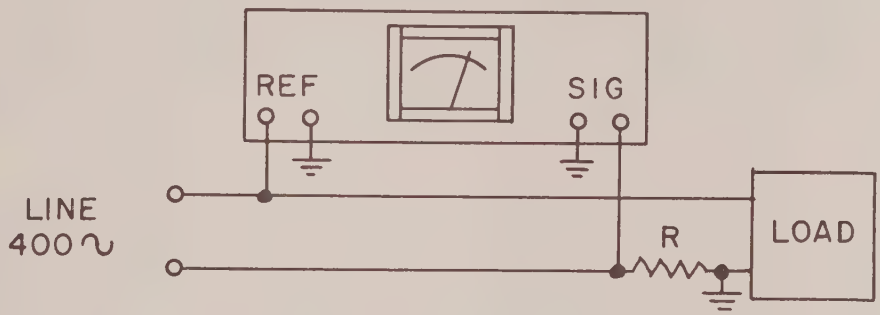


FIG. 8

VII - IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure (9) illustrates the manner in which the measurements can be made.

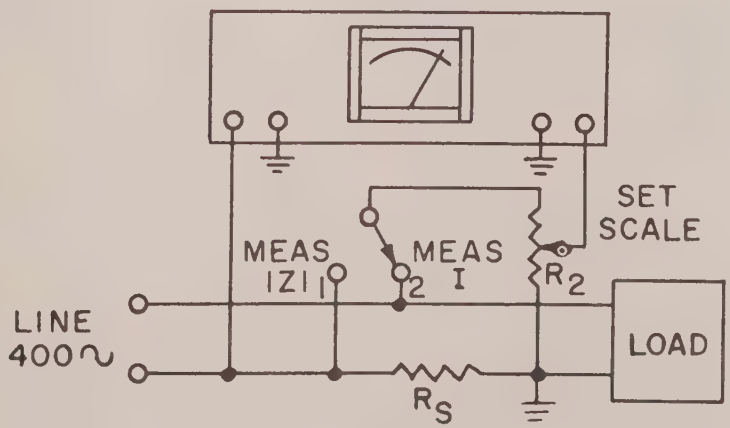


FIG. 9

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Using Table III as a guide, a precision ($\pm$ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale voltage on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE:

Load impedance = 470K
Rs = 1K
E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1V equals	Current Factor
10K	10K	1/volts
1K	1K	1/volts
100Ω	100Ω	1/volts
10Ω	10Ω	1/volts
1Ω	1Ω	1/volts

Measurement of AC Resistance and Reactance

By using the circuit of Figure (9) the real and imaginary components of the impedance can also be measured directly by using the current as a reference and measuring the in-phase and quadrature of the signal measured with the switch in position 2. The in-phase component will be the AC Resistance and the quadrature component will be the reactance with the sign determined as positive for a

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII - APPLICATIONS

Precision Ratiometer

In many analog computer systems the process of multiplication, division, addition, and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure (10) permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

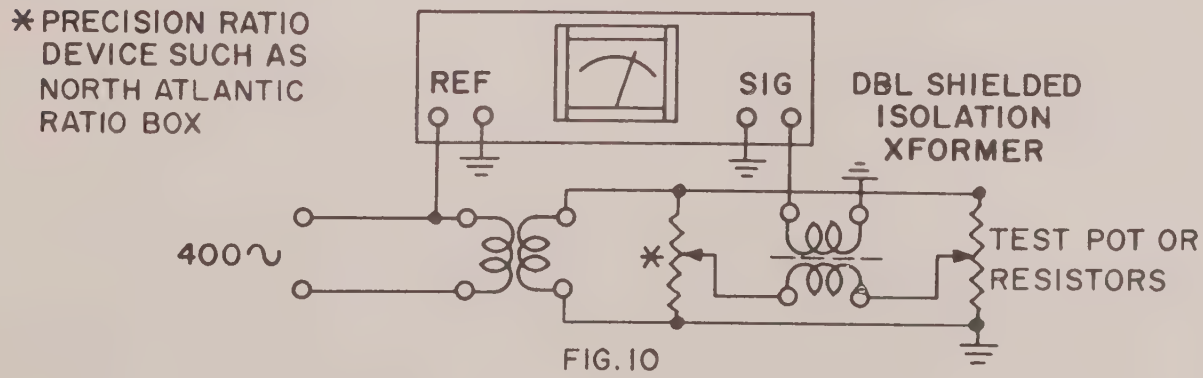


FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

transformer such as North Atlantic's T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

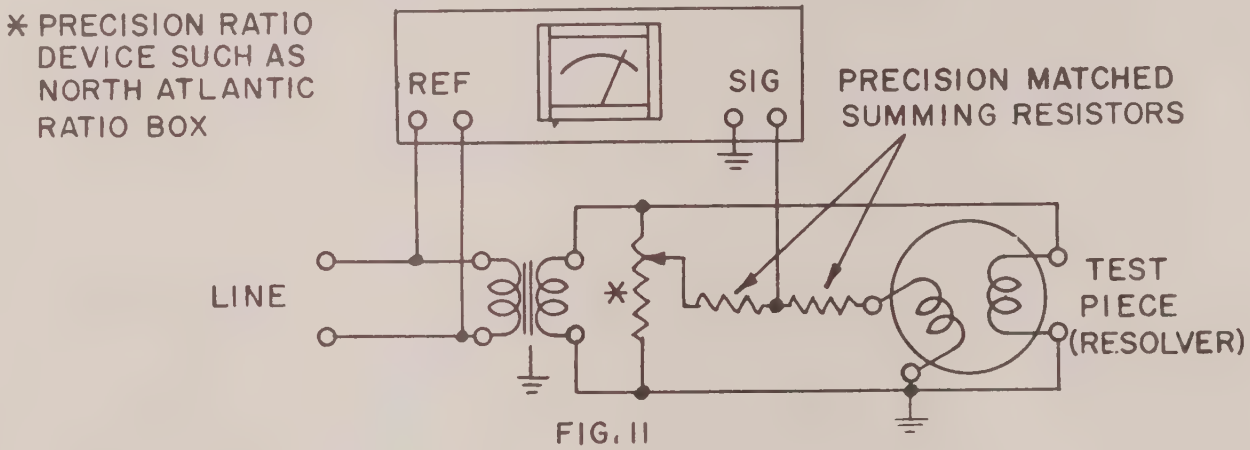


FIG. 11

Transducer Nulling

Applications involving transducers, such as differential transformers or E-Coil pickoffs, are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure (12) shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

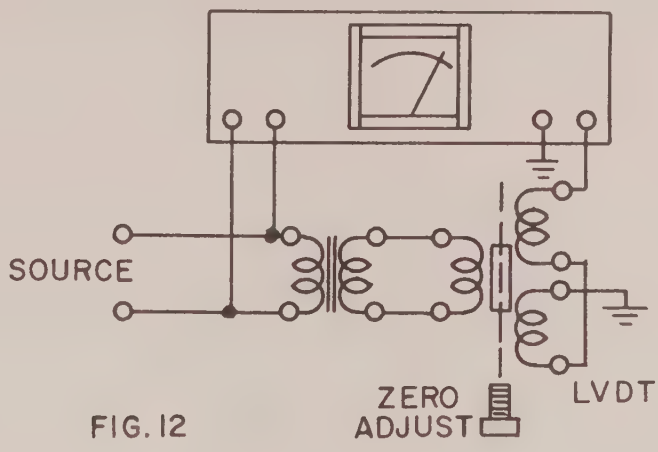


FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure (13) is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible nulls obtainable by conventional instrumentation.

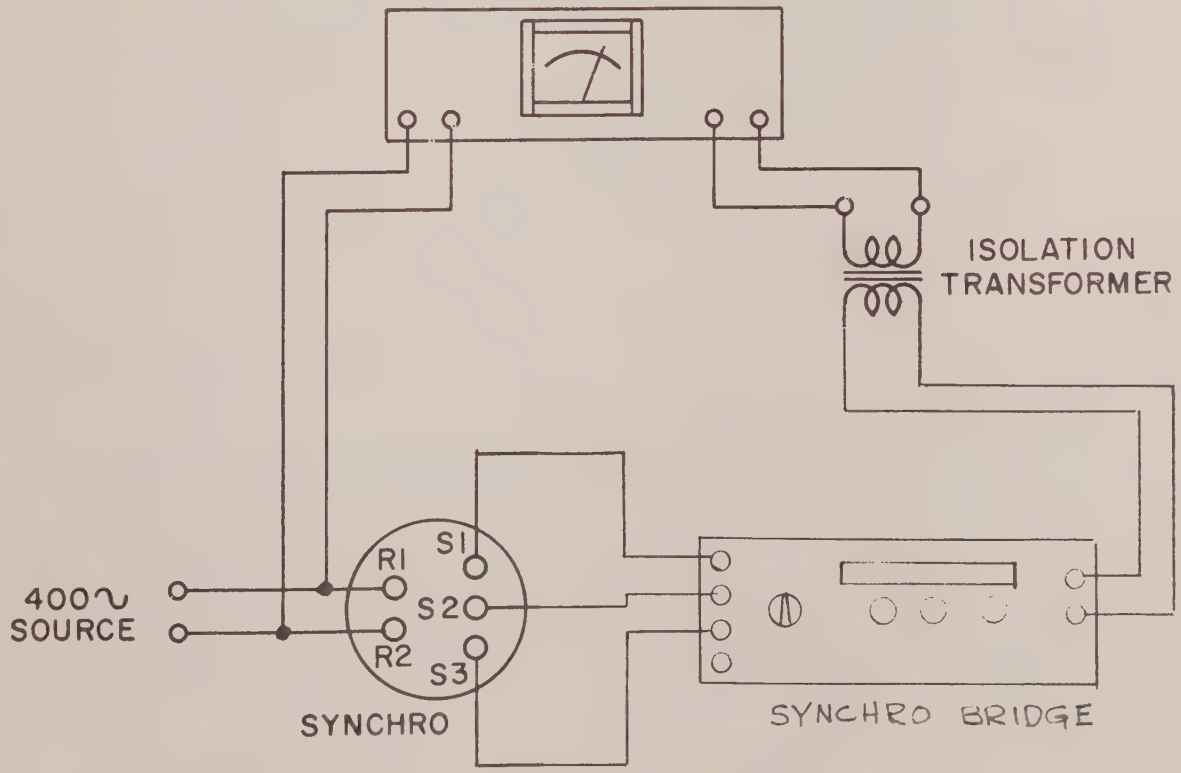


FIG. 13

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped waveforms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure (14) the task of alignment for maximum torque or output is straightforward since the meter reading is equivalent to motor output.

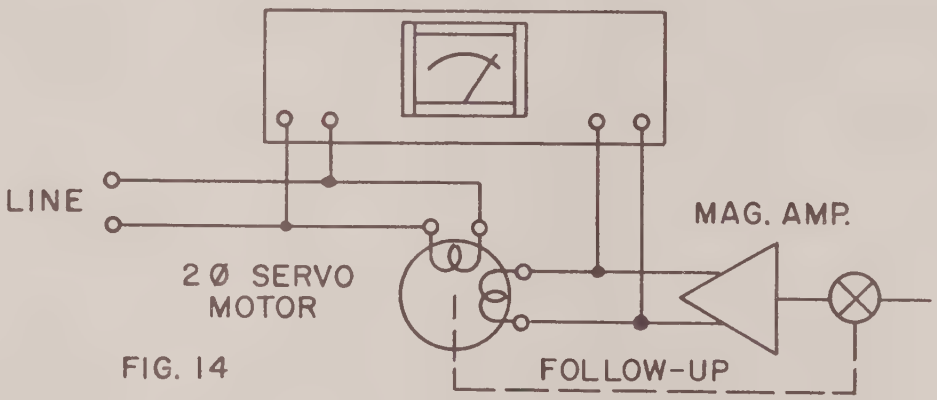


FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc., must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure (15) is a test setup used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

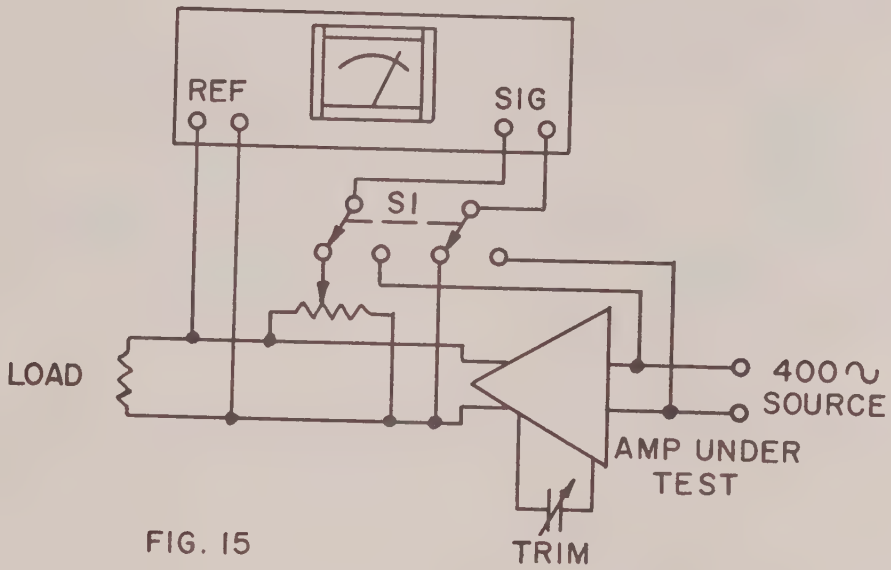


FIG. 15

Transformation Ratio

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure (16a) and (16b).

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

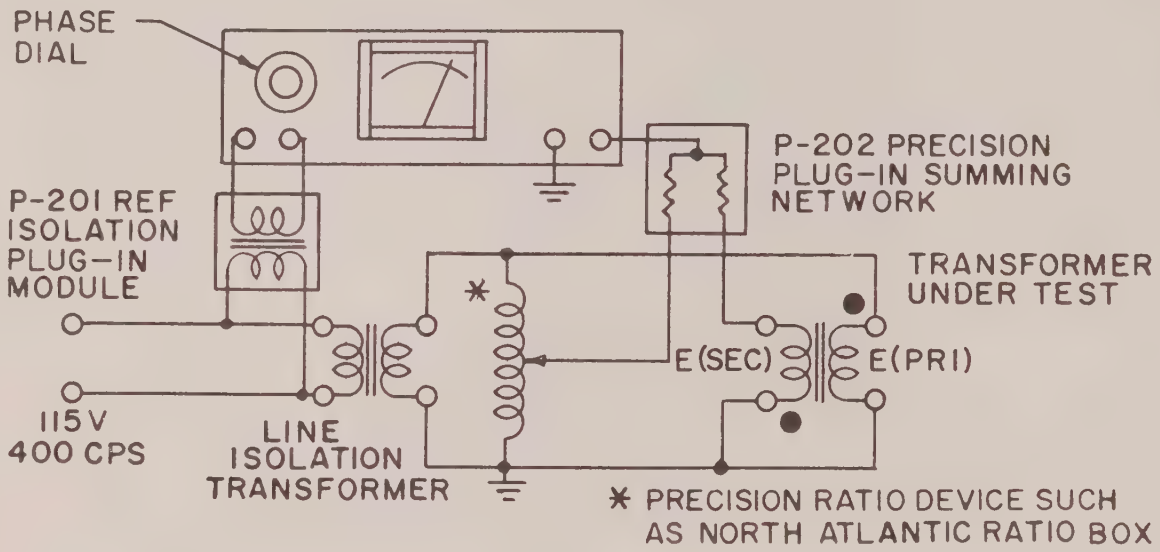


FIGURE 16(a)

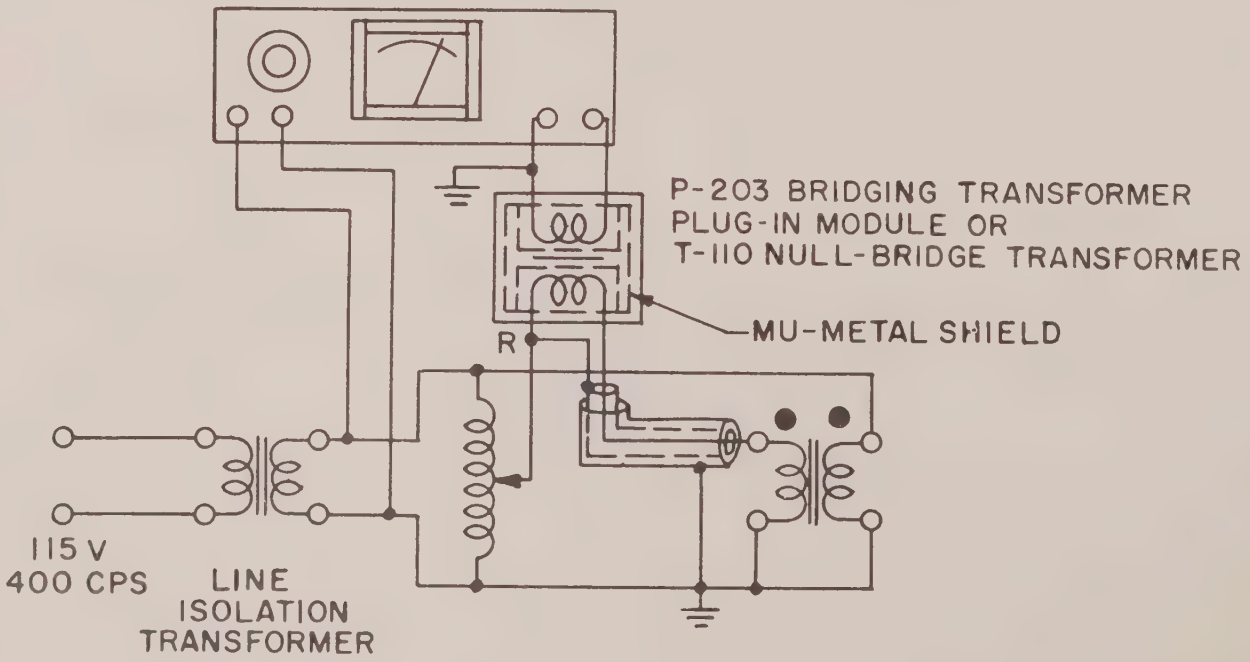


FIGURE 16(b)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

I. SUMMING NETWORK TECHNIQUES

In Figure (16a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test setup a line isolation transformer is utilized so as to avoid grounding one side of theline. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure (16a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure (16b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common-mode rejection and low input capacitance would suffice.

Measurement errors in Figure (16b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the Figure.

Common-mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each setup must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both setups require that the Phase Dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc., This is conveniently done by stepping the ratio device and adjusting the Phase Dial to produce zero output when the Function Selector is in the 90^{o} position. Operation will then be correct when the Function Selector is returned to the 0^{o} position.

Small Angle Measurements

Small angle measurements to better than $.01^{o}$ can also be made using the setups of Figure (16). The process consists of making the in-phase null, described in the foreoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}}$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

$$\text{Measured quadrature} = 30.0 \text{ millivolts}$$

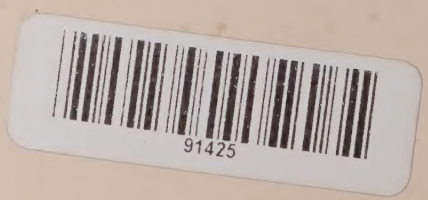
$$\text{Secondary voltage} = 30 \text{ volts}$$

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\cong 0.001 \times 57.3 = .057 \text{ degrees}$$

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600


91425